Original Article

Comparison of Skeletal and Dental Morphology in Asymptomatic Volunteers and Symptomatic Patients with Unilateral Disk Displacement Without Reduction*

Ioanna K. Gidarakou, DDS[a]; Ross H. Tallents, DDS[b]; Stephanos Kyrkanides, DDS, PhD[c]; Scott Stein, DMD[d]; Mark E. Moss, DDS, PhD[e]

Abstract: The purpose of this study was to evaluate the effect of unilateral disk displacement without reduction (UDDN) on the skeletal and dental pattern of affected individuals. There were 12 symptomatic female patients and 46 asymptomatic normal female volunteers. All study participants had bilateral high-resolution magnetic resonance scans in the sagittal (closed and open) and coronal (closed) planes to evaluate the temporomandibular joints. Linear and angular cephalometric measurements were taken to evaluate the skeletal, denture base, and dental characteristics of the two groups. ANOVA was used to compare the symptomatic subjects with the control subjects. A few skeletal differences were found. There was an overall reduction in length of the anterior (S-Na) and total (S-Ba) cranial base measurements in the UDDN group. The mandibular plane angle was steeper and the posterior ramal height (Ar-Go) was shorter in the symptomatic group. The only dental difference found was a relative infraeruption of the lower first molar. This study suggests that subjects with UDDN may manifest altered craniofacial morphology. Although the cephalometric measurements used did not account for any asymmetry, previous studies have shown that UDD may cause mandibular asymmetry. Presence of asymmetry and altered craniofacial morphology should alert the clinician especially while orthodontically treating children and surgical patients. (*Angle Orthod* 2003;73:121–127.)

Key Words: Disk; Unilateral; Skeletal; Alterations; Cephalometrics

INTRODUCTION

Temporomandibular joint disorder (TMD) is a collective term embracing a number of clinical problems that involve the masticatory musculature, the temporomandibular joint (TMJ) and associated structures or both.[1] Disk displacement with reduction (DDR) is frequently associated with a clicking sound and DD without reduction (DDN) is often associated with limitation of jaw opening.[2] DDN may be a more advanced stage of pathology in the TMJ and may progress to osteoarthritis.[3–6]

Autopsy studies in both young and mature adults show DD in 10–32% in the general population.[7,8] DD may occur in asymptomatic subjects with a prevalence ranging from 10% to 33%.[9–15] The reported high prevalence of DD in asymptomatic volunteers is not unique to the TMJ because magnetic resonance imaging studies of asymptomatic subjects in the knee, cervical spine, and lumbar spine indicate similar disease prevalences in asymptomatic subjects.[16–22] These studies demonstrate that DD can be present in patients without clinical signs and symptoms. On the other hand, not all TMJ pain, clicking, and limited jaw motion can be related to disk displacement within the TMJ in symptomatic patients. Paesani et al[23] studied 115 patients with signs and symptoms of TMD. Of these, 78% had unilateral or bilateral DD, but 22% had bilaterally normal TMJs.

[a] Resident, Department of Dentistry, Division of Orthodontics, University of Rochester School of Medicine and Dentistry, Rochester, NY.

[b] Professor, Department of Dentistry, Division of Orthodontics and Prosthodontics, Program Director Temporomandibular Joint Disorders, University of Rochester School of Medicine and Dentistry.

[c] Assistant Professor, Department of Dentistry, Assistant Chief of Division of Orthodontics, Craniofacial Research Core Coordinator, University of Rochester School of Medicine and Dentistry.

[d] Clinical Instructor, Department of Dentistry, Division of Orthodontics, University of Rochester School of Medicine and Dentistry.

[e] Assistant Professor, Department of Dentistry and Community and Preventive Medicine, University of Rochester School of Medicine and Dentistry.

Corresponding author: Ross H. Tallents, DDS, Department of Dentistry, Division of Orthodontics and Prosthodontics, Program Director Temporomandibular Joint Disorders, University of Rochester School of Medicine and Dentistry, 625 Elmwood Avenue, Rochester, NY 14620 (e-mail: ross_tallents@urmc.rochester.edu).

*The University of Rochester Research Subjects Review Board reviewed and approved the present study.

Accepted: August 2002. Submitted: June 2002.

Disk displacement may affect skeletal morphology. Nebbe et al[24] have suggested that adolescent female patients presenting for orthodontic treatment with bilateral DD show numerous angular and linear cephalometric differences compared with age-matched female controls. Nebbe et al[25] and Trpkova et al[26] also demonstrated that associations exist between subjects with DD and craniofacial morphology in a female adolescent sample in female orthodontic patients. Schellhas et al[27] and Dibbets et al[28] suggested that there are morphologic changes in children with DD and symptoms.

Brand et al,[29] Bosio et al[30] and Gidarakou et al[31,32] have also suggested that there are skeletal changes associated with DD. Patients referred for orthognathic surgery have also showed a high prevalence of DD,[5,33] and animal studies have suggested that there are morphologic changes associated with surgically created DD.[34–38] Unilateral DD may be associated with skeletal asymmetry as shown by clinical[39] and animal studies.[38,40] This study will evaluate asymptomatic volunteers (AV) and symptomatic subjects with unilateral DDN (UDDN) presenting with localized jaw joint pain for skeletal and dental morphologic changes.

MATERIALS AND METHODS

Materials

There were 46 asymptomatic normal female volunteers (AV) and 12 symptomatic age-matched females with UDDN.

The age range was 28.3 $\pm$ 6.7 y for the AV, whereas the mean age of the symptomatic subjects was 27.4 $\pm$ 9.2 y. All study participants read and signed an informed consent form before the study initiation that was approved by the Research Subjects Review Board of the University of Rochester, School of Medicine and Dentistry.

All asymptomatic volunteers answered a solicitation for examination and inclusion in the study. They were all examined by one investigator (Dr Tallents) and were accepted in the study following completion of:

1. They were accepted in the study after completion of a TMJ subjective questionnaire documenting the absence of jaw pain, joint noise, locking, and positive history of TMD.
2. They were accepted in the study after a clinical TMJ and dental examination for signs and symptoms commonly associated with TMD or internal derangement. All symptomatic subjects had localized jaw joint pain and pain on movement or when eating. Vertical opening and right and left mandibular movements were measured and recorded. The masseter, anterior, middle, and posterior temporalis and temporalis tendon area were digitally palpated. All asymptomatic volunteers demonstrated a maximal opening of at least 40 mm. The asymptomatic and symptomatic subjects were not blinded to the examiner.
3. All study participants had bilateral high-resolution magnetic resonance scans (MRIs) in the sagittal (closed and open) and coronal (closed) planes to evaluate the TMJs as described by Katzberg et al[41] and Westesson et al.[42] A detailed magnetic resonance assessment of both TMJs in all subjects was performed with a 1.5 T MR system (Signa scanner, General Electric Medical Systems, Milwaukee, Wis) using bilateral high-resolution 6 $\times$ 8 cm rectangular surface coils with the jaw in the closed and opened sagittal positions and closed coronal positions. An initial axial localizer with a 52-second scanning time was performed with a repetition time (TR) of 400 milliseconds, a echo time (TE) of 16 milliseconds, a field of view (FOV) of 18 cm, a slice thickness of 3 mm, and a 256 $\times$ 128 scanning matrix. These images were acquired to protocol paired orthogonal sagittal planes of both TMJs in the closed jaw position with a TR of 2000 milliseconds, TEs of 19 and 80 milliseconds, 3-mm image slice thicknesses, FOV of 10 cm, and a scanning matrix of 256 $\times$ 192. These were followed by paired sagittal plane open jaw images with a TR of 1500 milliseconds and TEs of 19 and 80 milliseconds. The final imaging sequence was with the jaw closed and acquired coronal images of both TMJs with a TR of 2000 milliseconds and TEs of 19 and 80 milliseconds. The sagittal images were perpendicular to the long axis of the condyle, and the coronal images were obtained parallel to the long axis of the condyle. The MR studies were independently assessed by two readers who used established criteria for disk displacement and were blinded to the clinical information. Each study participant was classified as AV or symptomatic UDDN.
4. All study participants had lateral cephalograms with the teeth in centric occlusion position and with the Frankfort Horizontal parallel to the floor. A Panorex and full-profile laminographs were also taken and will be evaluated in a future analysis. All cephalograms were taken on the same radiographic machine at the Orthodontic Clinic set for standardized exposure.

Null hypothesis

There are no statistically significant differences between skeletal, denture base, and dental characteristics of symptomatic UDDN patients compared with a sample of individuals with bilateral normal asymptomatic TMJs.

Cephalometric measurements

Figure 1 shows the cephalometric landmarks used. Tables 1–5 summarize the angular and linear cephalometric measurements used in this study. These measurements were categorized as cranial base measurements, profile analysis, denture base, dental pattern, and vertical relationship measurements.

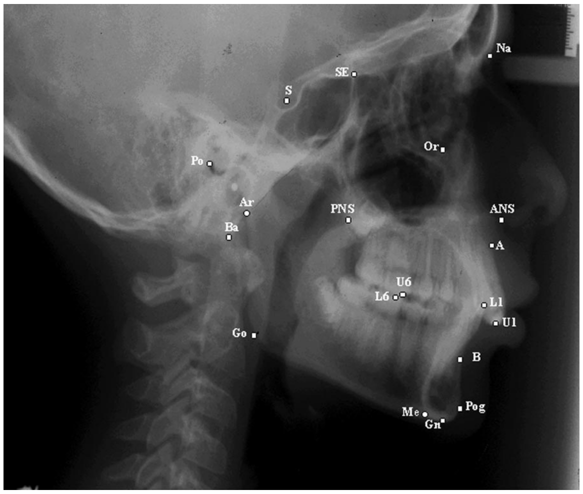

FIGURE 1. Cephalometric landmarks used.

TABLE 1. Cranial Base Measurements

	AV-N[a]		UDDN	
Measurements	Mean	SD	Mean	SD
S-Na	73.06	3.28	70.48*	5.06
Ba-Na	110.1	4.66	106.1*	5.84
Ba-S	47.18	2.54	45.82	2.46
Ba-S-Na	131.7	5.05	130.7	5.30

* *P* values equal to or less than .05 were considered significant.
[a] AV-N indicates asymptomatic volunteer with bilateral normal temporomandibular joints; UDDN, symptomatic unilateral disc displacement without reduction patient.

Statistical method

The analysis of variance (ANOVA) was used to reveal any statistically significant differences between the control group and the experimental group. All subjects were matched for age. The *P* value was calculated for each of the variables with a level of significance for each test established at .05.

Error of measurement

Errors in landmark localization during tracing were evaluated by retracing 20 cephalograms in the experimental and control groups. The reliability of tracing, landmark identification, and analytical measurements had intraclass correlation coefficient greater than 0.92.

RESULTS

Tables 1–5 summarize the findings of the measurements.

Table 1 demonstrates that there are cranial base differences between the two groups. The anterior (S-Na) and posterior (Ba-Na) cranial base lengths were reduced for the UDDN group. Tables 2–4 demonstrate no significant differences in profile analysis, denture base measurements, or the denture pattern. The measurements of the vertical relationships showed a steeper mandibular plane angle and a shorter ramal height in the UDDN subjects (Table 5). The lower first molar was relatively infra-erupted in the symptomatic group. No significant differences were found in the profile analysis, the denture base measurements, and the denture pattern. The significant measurements are shown in Figures 2 and 3.

TABLE 2. Profile Analysis

	AV-N[a]		UDDN	
Measurements	Mean	SD	Mean	SD
FH to Na-Pg	89.18	3.10	88.13	3.27
FH to Na-A	90.71	2.99	90.50	3.22
Na-A-Pog	2.99	6.23	5.04	7.43

* *P* values equal to or less than .05 were considered significant.
[a] AV-N indicates asymptomatic volunteer with bilateral normal temporomandibular joints; UDDN, symptomatic unilateral disc displacement without reduction patient.

TABLE 3. Denture Base Measurements

	AV-N[a]		UDDN	
Measurements	Mean	SD	Mean	SD
ANS-PNS	56.30	3.84	55.61	4.58
SNA	81.81	3.74	80.66	3.58
SNB	79.18	3.69	77.36	2.96
ANB	2.64	2.52	3.30	2.91
A-B to FP	−4.99	3.54	−5.73	3.97

* *P* values equal to or less than .05 were considered significant.
[a] AV-N indicates asymptomatic volunteer with bilateral normal temporomandibular joints; UDDN, symptomatic unilateral disc displacement without reduction patient.

TABLE 4. Denture Pattern

	AV-N[a]		UDDN	
Measurements	Mean	SD	Mean	SD
FH to OP	5.14	3.67	7.55	3.81
U1 to L1	128.2	8.41	128.0	12.98
U1 to PP	109.2	6.81	111.0	5.85
U1 to FH	110.7	6.85	111.5	6.01
U1 to S-Na	101.8	6.87	101.6	5.25
U1 to A-Pog	23.30	6.70	26.03	7.87
U1 perpendicular to A-Pog	7.38	2.06	7.52	2.56
L1 to MP	5.89	7.18	2.07	12.63
L1 to OP	25.10	6.92	22.93	10.56
L1 to A-Pg	27.70	4.44	25.92	6.37
L1 perpendicular to A-Pog	4.14	1.84	3.88	1.58
Overbite (perpendicular to FH)	2.88	1.70	2.39	2.53
Overjet (parallel to FH)	3.07	1.18	3.19	1.71

* *P* values equal to or less than .05 were considered significant.
[a] AV-N indicates asymptomatic volunteer with bilateral normal temporomandibular joints; UDDN, symptomatic unilateral disc displacement without reduction patient.

DISCUSSION

Disk displacement is quite prevalent in the asymptomatic population. A high prevalence of disk displacement in

TABLE 5. Vertical Relationships

	AV-N[a]		UDDN	
Measurements	Mean	SD	Mean	SD
MP to FH	24.36	4.91	28.40*	6.26
S-Gn to FH	58.02	2.92	59.62	2.87
Na-ANS (UFH)	53.80	3.06	53.67	2.12
ANS-Me (LFH)	65.99	4.83	64.34	5.42
Na-Me (TFH)	119.8	5.49	118.0	5.86
UFH: TFH	44.94	2.37	45.58	2.33
SE-PNS	49.20	3.15	48.04	3.74
Ar-Go	47.86	5.11	43.21*	6.15
U6 perp PP	23.45	1.93	23.93	2.35
U1 perp PP	29.23	2.71	29.07	3.05
L6 perp MP	32.37	2.40	29.89*	3.93
L1 perp MP	41.97	2.49	40.33	3.52
PP to OP	6.65	3.80	8.07	3.96
PP to MP	25.86	4.99	28.92	7.39
PP to FH	−1.09	3.54	−1.17	2.89
Ar-Go-Gn	126.5	5.55	129.4	9.24
Anti-gonial notch	171.7	7.58	168.6	6.74

* *P* values equal to or less than .05 were considered significant.
[a] AV-N indicates asymptomatic volunteer with bilateral normal temporomandibular joints; UDDN, symptomatic unilateral disc displacement without reduction patient.

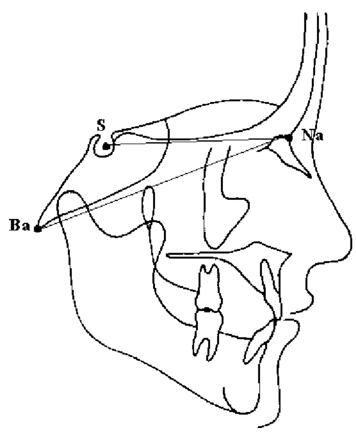

FIGURE 2. Significant measurements of the cranial base (S-Na, Ba-Na).

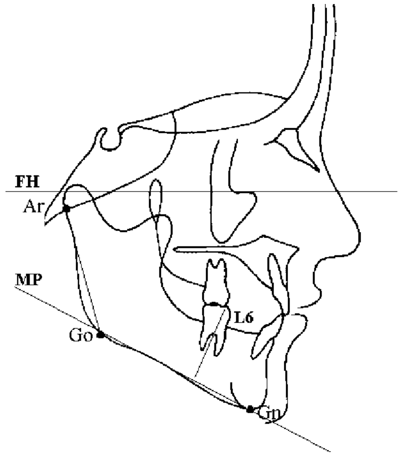

FIGURE 3. Significant measurements of the vertical relationships (MP to FH, Ar-Go, L6 perpendicular to MP).

asymptomatic volunteers has been suggested. Westesson et al[9] found 15% of their asymptomatic volunteers to have unilateral DD using TMJ arthrography. Tallents et al in a study of evaluation of TMJ sounds in asymptomatic volunteers found that 24% had one or two joints with DD as diagnosed by MRI.[10] Kircos et al[15] found a 32% prevalence of DD in asymptomatic volunteers. Ribeiro et al[11] found the prevalence of DD in asymptomatic children and young adults to be 34%, whereas 86% of the symptomatic temporomandibular disorder patients had DD. Their results showed that 13.8% had bilateral symptomatic but normal joints, 28% had unilateral DD, and 58% had bilateral DD. They suggested that DD is relatively common in asymptomatic volunteers. A high prevalence of DD in asymptomatic volunteers is not unique to the TMJ. Magnetic resonance imaging studies of asymptomatic subjects in the knee, cervical spine, and lumbar spine indicate similar disease prevalences in asymptomatic subjects in these body parts as well.[16–21] Brunner et al[22] showed that half of the asymptomatic athletes included in the study had significant baseline knee MRI scan abnormalities. Oberg et al macroscopically examined the right TMJs of 155 cadavers of different ages regarding the shape, size, and appearance of the joint surfaces.[7] They found that with increasing age the number of joints with local changes in the shape, remodeling, or arthritic changes of the articular surfaces increased. The arthritic changes were significantly more prevalent in women.

Disk displacement may cause altered skeletal morphology.[5,25–27,31,32] In this study, we evaluated the effect of UDDN on the skeletal and dental patterns of the affected individuals. There was an overall reduction in length of the S-Na and the Ba-Na cranial base measurements in the UDDN group. This agrees with Nebbe et al[25] who found decreased Ba-Na length. They also found a more acute cranial base angle, which was not significantly different in our group, but did not clarify whether their subjects had DD with or without reduction. We found no differences in SNB or facial plane angle in the UDDN group. This suggests that the anteroposterior position of the mandible is not affected in our symptomatic sample. Bosio et al,[30] on the other hand, found a smaller mean SNB angle in patients with bilateral DD compared with asymptomatic volunteers. We can then speculate that the unilateral nonreducing disk does not affect the A-P mandibular position at least in our sample.

There were also significant differences in the vertical relationships. The mandibular plane angle was steeper and the posterior ramal height (Ar-Go) was shorter in the symptomatic group. Dibbets et al[28] and Nebbe et al[25] have also reported steeper mandibular plane and shorter ramal heights in children and adolescents presenting with degenerative joint disease and DD, respectively. We did not distinguish left from right side, but we may attribute the shortness of the posterior ramal height to the DDN. Animal models with DD also showed reduced ramal height. Shortening and flattening of the condylar head with loss of posterior height has been demonstrated in the growing rabbit after unilateral surgically created DD.[38,40] Legrell et al[40] found that rabbits with surgically created UDD exhibited a deviant growth pattern and mandibular asymmetry. They concluded that UDD can cause mandibular asymmetry in growing rabbits including shortening of the ramus and excessive vertical growth along the lower mandibular border and the gonial angle region. This agrees with the clinical study by Trpkova et al[26] who investigated the amount of craniofacial asymmetry in female orthodontic patients with unilateral or bilateral TMJ DD compared with female controls without DD using frontal radiographs. Females with bilateral DD had significantly greater asymmetry in the vertical position of the antegonion. If the DD was more advanced on one side, then the ipsilateral ramus was shorter, resulting in significant asymmetry of the mandible. The authors concluded that a female patient with unilateral or bilateral DD may present with or develop a vertical mandibular asymmetry. Tallents et al[39] studied 12 consecutive patients presenting with facial asymmetry thought to represent unilateral condylar hyperplasia. But half of these patients were found to have unilateral DD occurring on the short side. Therefore, the clinician should be aware of the possibility of the presence of DD in asymmetric patients.

Our study agrees with previous studies, which have suggested that DD can affect skeletal morphology and symmetry. Link and Nickerson[5] and Schellhas et al[27] have suggested that there is a cause and effect relationship between DD and facial growth. Nebbe et al[25] have suggested that adolescent female patients presenting for orthodontic treatment with bilateral DD show numerous angular and linear cephalometric differences compared with age-matched female controls. There was an increased mandibular and palatal plane relative to sella-nasion, posterior rotation of the mandible, a decrease in Rickett's facial axis, reduced posterior facial height, and ramal height as well as a slight increase in middle anterior facial height and a decreased posterior cranial base height.[25] Schellhas et al[27] in their study of children 14 years of age or younger concluded that TMJ derangements are both common in children and may contribute to the development of retrognathia, with or without asymmetry. In cases of lower face asymmetry, the chin was uniformly deviated towards the smaller or more degenerated TMJ. They proposed that in the growing facial skeleton, DD either retards or arrests condylar growth, which results in decreased vertical dimension in the proximal mandibular segment(s) with ultimately mandibular deficiency or asymmetry.[27] Dibbets et al[28] showed that children with symptoms of dysfunction form a morphologically clearly recognizable group. Their profile was more Class II; they had a shorter corpus and ramus and exhibited decreased posterior facial height. They concluded that TMJ dysfunction might be associated with the growth of the mandible.[28] Brand et al[29] indicated that patients with DD had significantly shorter maxillary and mandibular lengths compared with asymptomatic normal individuals with normal TMJs. This investigation did not distinguish between unilateral and bilateral DD and could not account for any asymmetries because the right and left landmarks in the cephalometric radiograph were averaged. Increased prevalence of DD has been found in patients with mandibular retrognathia presenting for orthognathic surgery. Link and Nickerson[5] studied 39 patients referred for orthognathic surgery, 38 of who were found to have DD before surgery. All their open-bite patients and 88% of the patients with Class II malocclusion had bilateral DD. They suggested that DD may be a contributing factor in the development of dentofacial deformities and that new loading of deranged joints after orthognathic surgery may be a cause of a new arthrosis and skeletal relapse, suggesting a progression of TMJ pathology. They suggested that DD should be suspected in individuals with sagittal mandibular deficiency, vertical ramus deficiency, or a unilateral sagittal deficiency. The high degree of association of DD with mandibular deficiency suggests that DD may have a role in causing these deformities. That is, loss of condylar height or growth secondary to the DD caused or worsened the horizontal or vertical ramus mandibular deficiency.[5] Schellhas et al,[33] in their retrospective study of 100 consecutive orthognathic surgery candidates, found that DD was prevalent, especially in patients who exhibited change in their facial contour in the year before the evaluation. The degree of joint degeneration directly paralleled the severity of retrognathia. They concluded that TMJ DD is common in cases of mandibular retrusion and leads to the facial morphology in a high percentage of patients.

We did not find a retropositioned mandible in this sample. There are two reasons for this, (1) the sample size is small and (2) mandibular retropositioning may express itself with bilateral disc displacement, with or without degenerative joint disease. We have shown in subjects with bilateral derangements that the mandible is retropositioned.

CONCLUSIONS

The results of this study show that alterations in skeletal morphology may be associated with DDN. The mechanisms by which DD is produced or the mechanisms that cause this skeletal alteration are yet to be clarified. We found altered skeletal morphology in our symptomatic sample with UDDN. Other studies have also demonstrated that UDDN may cause facial asymmetry.[26,38,39] This study and the studies mentioned suggest that UDDN may affect the skeletal morphology, symmetry, and growth pattern of the affected individual. The clinician should be aware of these possibilities, especially while treating children and orthognathic surgery candidates.

REFERENCES

1. Okesson JP. *Orofacial Pain. Guidelines for Assessment, Diagnosis and Management.* Carol Stream: Quintessence Publishing Co, Inc.; 1996:116.
2. Katzberg RW, Westesson PL, Tallents RH, Drake CM. Orthodontics and temporomandibular joint disorders. *Am J Orthod Dentofacial Orthop.* 1996;109:515–520.
3. Westesson P-L, Rohlin M. Internal derangement related to osteoarthrosis in temporomandibular joint autopsy specimens. *Oral Surg.* 1984;57:17–22.
4. Eriksson L, Westesson P-L. Clinical and radiologic study of patients with anterior disk displacement of the temporomandibular joint. *Swed Dent J.* 1983;7:55–64.
5. Link JJ, Nickerson JW Jr. Temporomandibular joint internal derangements in an orthognathic surgery population. *Int J Adult Orthod Orthognath Surg.* 1992;7:161–169.
6. Yamada K, Hiruma Y, Hanada K, Hayashi T, Koyama J, Ito J. Condylar bony change and craniofacial morphology in orthodontic patients with TMD symptoms: a pilot study using helical computed tomography and magnetic resonance imaging. *Clin Orthod Res.* 1999;2:133–142.
7. Oberg T, Carlsson GE, Fajers CM. The Temporomandibular Joint. A morphometric study on a human autopsy material. *Acta Odontol Scand.* 1971;29:349–384.
8. Solberg WK, Hansson TL, Nordstrom B. The temporomandibular joint in young adults at autopsy: a morphologic classification and evaluation. *J Oral Rehabil.* 1985;12:303–321.
9. Westesson PL, Eriksson L, Kurita K. Reliability of a negative clinical temporomandibular joint examination: prevalence of disk displacement in asymptomatic temporomandibular joint. *Oral Surg Oral Med Oral Pathol.* 1989;68:551–554.
10. Tallents RH, Hatala M, Katzberg RW, Westesson PL. Temporomandibular joint sounds in asymptomatic volunteers. *J Prosthet Dent.* 1993;69:298–304.
11. Ribeiro RF, Tallents RH, Katzberg RW, Murphy WC, Moss ME, Magalhaes AC, Tavano O. The prevalence of disk displacement in symptomatic and asymptomatic volunteers aged 6 to 25 years. *J Orofacial Pain.* 1997;11:37–46.
12. Tallents RH, Katzberg RW, Murphy W, Proskin H. Magnetic resonance imaging findings in asymptomatic volunteers and symptomatic patients with temporomandibular disorders. *J Prosthet Dent.* 1996;75:529–533.
13. Katzberg RW, Westesson PL, Tallents RH, Drake CM. Orthodontics and temporomandibular joint internal derangement. *Am J Orthod Dentofacial Orthop.* 1996;109:515–520.
14. Morrow D, Tallents RH, Katzberg RW, Murphy WC, Hart TC. Relationship of other joint problems and anterior disk displacement in symptomatic TMD patients and in asymptomatic volunteers. *J Orofacial Pain.* 1996;10:15–20.
15. Kircos LT, Ortendhal DA, Mark A, Arakawa M. Magnetic resonance imaging of the TMJ disk in asymptomatic volunteers. *J Oral Maxillofac Surg.* 1987;45:852–854.
16. Nagendak WG, Fernandez FR, Halburn LK, Teitge RA. Magnetic resonance imaging of meniscal degeneration in asymptomatic knees. *J Orthop Res.* 1990;8:311–312.
17. Kornick J, Trefelner ME, McCarty S, Lang R, Lynch K, Jokl P. Meniscal abnormalities in the asymptomatic population in MR imaging. *Radiology.* 1990;177:463–465.
18. Boden SD, Davis DO, Dina TS, Staller DW, Brown SD, Vailas JC, Labropoulos PA. A prospective and blinded investigation of magnetic resonance imaging of the knee: abnormal findings in asymptomatic subjects. *Clin Orthop.* 1992;282:177–185.
19. Shellock FG, Morris E, Deutsch AL, Mink JH, Kerr R, Boden SD. Hematopoietic marrow hyperplasia: high prevalence on MR images of the knee in asymptomatic marathon runners. *Am J Roentgenol.* 1992;158:335–338.
20. Boden SD, McCowin PR, Davis DO, Dina TS, Mark AS, Wiesel S. Abnormal magnetic resonance scans of the cervical spine in asymptomatic subjects. *J Bone Joint Surg (Am).* 1990;72:1174–1184.
21. Boden SD, Davis DO, Dina TS, Patronas NJ, Wiesel SW. Abnormal magnetic resonance scans of the lumbar spine in asymptomatic subjects: a prospective investigation. *J Bone Joint Surg (Am).* 1990;72:403–408.
22. Brunner MC, Flower SP, Evancho AM, Allman FL, Apple DF, Fajman WA. MRI of the athletic knee. Findings in asymptomatic professional basketball and collegiate football players. *Invest Radiol.* 1989;24:72–75.
23. Paesani D, Westensson PL, Hatala M, Tallents RH, Kurita K. Prevalence of temporomandibular joint internal derangement in patients with craniomandibular disorders. *Am J Orthod Dentofacial Orthop.* 1992;101:41–47.
24. Nebbe B, Major PW, Prasad NGN. Adolescent female craniofacial morphology associated with advanced bilateral TMJ disk displacement. *Eur J Orthod.* 1998;20:701–712.
25. Nebbe B, Major PW, Prasad NGN. Female adolescent facial pattern associated with TMJ disk displacement and reduction in disk length: part I. *Am J Orthod Dentofacial Orthop.* 1999;116:168–176.
26. Trpkova B, Major P, Nebbe B, Prasad N. Craniofacial asymmetry and temporomandibular internal derangement in female adolescents: a posteroanterior cephalometric study. *Angle Orthod.* 2000;70:81–88.
27. Schellhas KP, Pollei SR, Wilkes CH. Pediatric internal derangements of the temporomandibular joint: effect on facial development. *Am J Orthod Dentofacial Orthop.* 1993;104:51–59.
28. Dibbets JMH, Van Der Weele LT, Uildriks AKJ. Symptoms of TMJ dysfunction: indicators of growth patterns? *J Pedod.* 1985;9:265–284.
29. Brand JW, Nielson KJ, Tallents RH, Nanda RS, Currier GFC, Owen WL. Lateral cephalometric analysis of skeletal patterns in patients with and without internal derangement of the temporomandibular joint. *Am J Orthod Dentofacial Orthop.* 1995;107:121–128.
30. Bosio JA, Burch JG, Tallents RH, Wade DB, Beck FM. Lateral cephalometric analysis of asymptomatic volunteers and symptomatic patients with and without temporomandibular joint displacement. *Am J Orthod Dentofacial Orthop.* 1998;114(3):248–255.
31. Gidarakou IK, Tallents RH, Kyrkanides S, Stein S, Moss ME. Comparison of skeletal and dental morphology in asymptomatic volunteers and symptomatic patients with bilateral disk displacement with reduction. Angle Orthod. In press.
32. Gidarakou IK, Tallents RH, Kyrkanides S, Stein S, Moss ME. Comparison of skeletal and dental morphology in asymptomatic volunteers and symptomatic patients with bilateral degenerative joint disease. Angle Orthod. In press.
33. Schellhas KP, Piper MA, Bessette RW, Wilkes CH. Mandibular retrusion, temporomandibular joint derangement and orthognathic surgery planning. *Plastic Recon Surg.* 1992;90:218–232.
34. Macher DJ, Westesson PL, Brooks SL, Hicks D, Tallents RH. Temporomandibular joint surgically created disk displacement causes arthrosis in the rabbit. *Oral Surg Oral Med Oral Pathol.* 1992;73:645–649.
35. Qadan S, Macher DJ, Tallents RH, Kyrkanides S, Moss ME. The effect of surgically induced anterior disk displacement of the tem-

poromandibular joint on the midface and cranial base. *Clin Orthod Res.* 1999;2:124–132.

36. Tallents RH, Macher DJ, Rivoli P, Scapino R, Puzas JE, Katzberg WR. An animal model for meniscus displacement in the rabbit. *J Craniomandib Disord Facial Oral Pain.* 1990;4:233–240.
37. Legrell PE, Reidel J, Nylander K, Horstedt P, Isberg A. Temporomandibular joint condyle changes after surgically induced nonreducing disk displacement in rabbits: a macroscopic and microscopic study. *Acta Odontol Scand.* 1999;57:290–300.
38. Hatala MP, Tallents RH, Spoon M, Subtelny JD, Kyrkanides S. Effect of surgically created disk displacement on mandibular asymmetry in the growing rabbit. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 1996;82:625–633.
39. Tallents RH, Guay JA, Katzberg RW, Murphy W, Proskin H. Angular and linear comparisons with unilateral mandibular asymmetry. *J Craniomandib Disord Facial Oral Pain.* 1991;5:135–142.
40. Legrell PE, Isberg A. Mandibular height asymmetry following experimentally induced temporomandibular joint disk displacement in rabbits. *Oral Surg Oral Med Oral Pathol Endod.* 1998; 86:280–285.
41. Katzberg RW, Westesson PL, Tallents RH, Anderson R, Kurita K, Manzione JV, Totterman S. Temporomandibular joint: magnetic resonance assessment of rotational and sideways disk displacement. *Radiology.* 1988;169:741–748.
42. Westesson PL, Katzberg RW, Tallents RH, Sanchez-Woodworth RE, Svensson SA. Temporomandibular joint: comparison of MR images with creosectional anatomy. *Radiology.* 1987;164:59–64.
43. Gidarakou IK, Tallents RH, Kyrkanides S, Stein S, Moss M. Comparison of skeletal and dental morphology in asymptomatic volunteers and symptomatic patients with bilateral disc displacement without reduction. Angle Orthod. In press.